Online particle size distribution estimation of a mixture of similar sized particles with acoustic emissions

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Online particle size distribution estimation of a mixture of similar sized particles with acoustic emissions

Ejay Nsugbe, Andrew Starr, Ian Jennions and Cristobal Ruiz Carcel

Cranfield University, College Rd, Cranfield , MK43 0AL

e.nsugbe@cranfield.ac.uk

Abstract. Particle processing plants regard the Particle Size Distribution (PSD) as a key quality factor as it influences the bulk and flow properties of the particles. In this work, Acoustic Emission (AE) is used to estimate the PSD of a mixture that comprise of similar sized particles. The experiments involved the use of regular sized particles (glass beads) and with the aid of a time domain based threshold analysis of the particle impacts the PSD of the mixtures could be estimated.

1. Introduction and related works summary

The Particle Size Distribution (PSD) is an important quality attribute of various kinds of particle processing settings that range from granulators, batch agglomeration mixers, coal milling plants, fluidised beds and pneumatically conveyed systems.[1-5] The need for particle size monitoring methods has seen several technologies developed, some of which have been used in industrial based settings while others are still limited controlled laboratory based systems.[4]

Notable AE based particle sizing began with the work of Leach and Buttle, who observed that a linear relationship exists between particle sizes and their respective AE amplitude.[7][8] The work done by Buttle et al in a vacuum tube assisted in the validation of Leach's theory and provided a mathematical representation of this principle which is referred to as the signal shaping chain and can be seen in figure 1.[8] Buttle quantitatively sized particles using a quantitative sizing technique but due to the deconvolution of each impact peak associated with the signal analysis, this method would be unsuitable to industrial cases where the particle events overlap each other.[2,5,8]

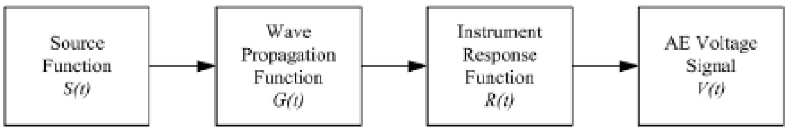

Figure 1. Signal shaping chain **[5][19]**

Data driven techniques were used by Bastari and Chen to estimate particle sizes, due to their approach being structured around neural networks a complete understanding of the decision making process is not fully understood.[3] Hu and Ren applied a threshold and wavelet based methods respectively to estimate particle sizes. Hu et al's method was unable to accurately estimate the sizes of particle under

90 microns while Ren et al's method was seen to not be adaptive enough to work in processes where the final powder mix ratio varies significantly. [4,5]
This paper details the results of an experimental study on a research based on the estimation of the PSD of powder mixtures with AE using a novel signal processing method. [2,9,12] With the goal of this experiment in this report being to observe the performance of the previously designed signal processing method in estimating the PSD of powder mixtures that comprise of similar sized particles.

2. Signal processing approach and experimental setup

The acquired signal will be analysed with analysed with a multiple threshold signal processing method as designed in our previous study. [2,9,12] The principle for the designed multiple threshold method is stemmed from the dynamics of the signal shaping chain, where each particle distribution would have a set of AE amplitudes which can be correlated to the particles themselves.
The same experimental rig as detailed in previous study would be used in this paper, the rig is based around the free flow of powders dispensed at a known rate impelled against the force of gravity on a target plate. [2,9,12]

3. Results and discussion

3.1. Glass beads mixture

Two sets of glass beads were used for the experiments in this section and were mixed in different mix ratios, details of their respective physical properties can be seen in Table 1.

Table 1. Glass beads physical properties

Particle Class	Particle Size Distribution(microns)	Density(g/cm^3)	% Density Difference
Class1	150-212	1.49	2.6%
Class2	212-300	1.53	

Each powder mix ratio was repeated 5 times and a constant mass of powder was dispensed into the experimental funnel each time while the data was analysed using the signal processing method used in previous study.[12] Using the rules set out in the designed signal processing approach, the optimal correlation plot which was chosen as the PSD estimation model can be seen in figure 2. The best correlation plot showed a linear relationship existed between the different particle mixtures and their associated amplitude mean values. The accuracy of this linear model was investigated and a set of particle mixtures were mixed, dispensed and analysed to serve as the model validation mixtures. For the validation of the particle sizing model, each set of AE validation dataset was analysed with the amplitude threshold parameters which produced the best correlation plot, from this this threshold region the mean AE amplitude was extracted and this value is then correlated with its respective particle size using the final chosen correlation plot.

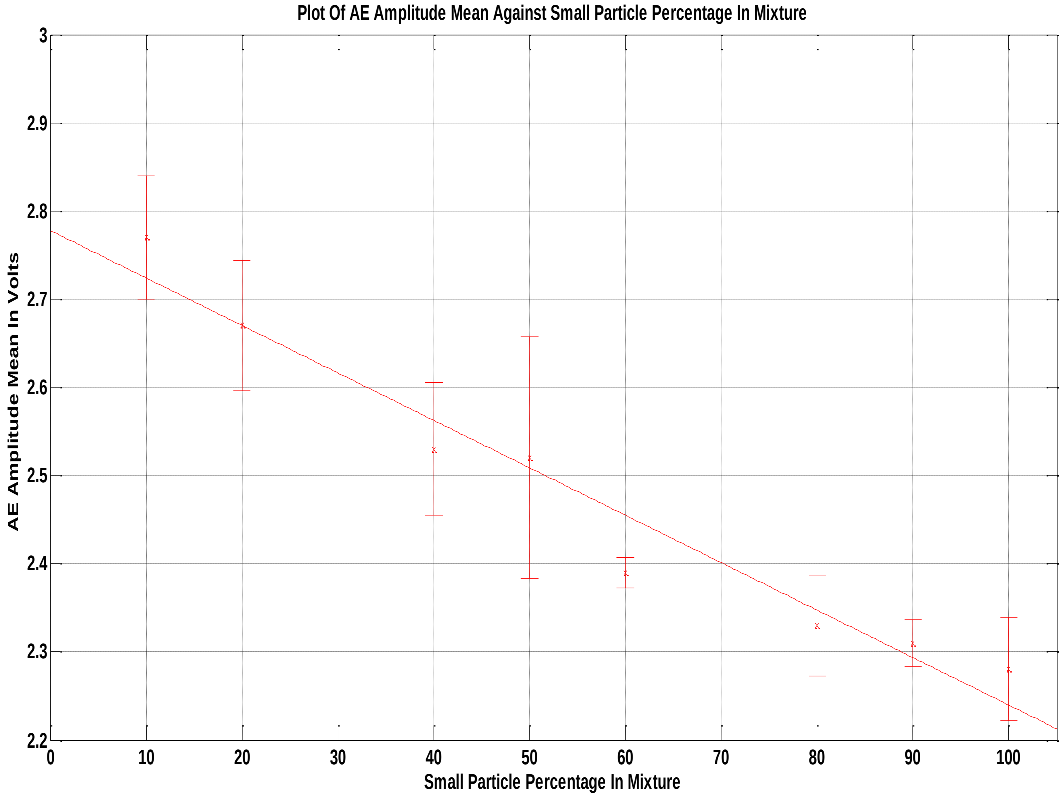

Figure 2. Correlation plot of ae amplitude mean against small particle (Class 1) percentage in mixture

The results of the linear model validation exercise can be seen in figure 3, the model was able to estimate particle mix ratio with an average absolute error of 12%. This would suggest that a good estimation of particle size can be achieved for mixtures which comprise of particles with similar sizes, using the designed multiple threshold signal processing method.

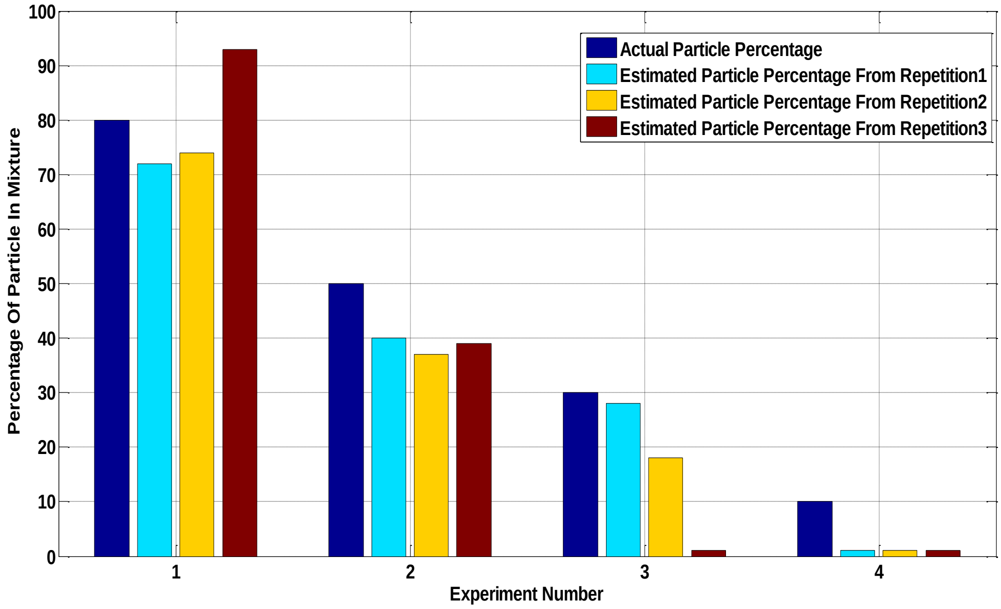

Figure 3. Chart comparing percentage of class 1 glass beads particle against amount estimated by model

4. Conclusion

This work investigated the use of AE to estimate the PSD of mixtures of powders with similar sized particles. The signal processing method used is based on a hybrid PSD estimation method designed in a previous study. [2,9,12] The experiments carried out involved a mixture of two sets of regular sized glass beads whose percentage bulk density difference between them was 2.6%. With the particle bulk density noted as an important factor which influences the output amplitude of a particle during impact. [13]

The result from the experiments conducted showed that the signal processing approach was capable of estimating PSD of the glass beads mixture to within 12% average absolute error. It should be noted that although the chart in figure 2 appears to be estimating only the class 1 particles, the operating assumption is that hence it is a two particle mixture if the amount of one particle group can be estimated with the particle estimation model, the amount of the second particle in the mixture can then be simply calculated. The next set of experiment in this study would involve a mixture comprising of a set of regular and irregular sized particles to observe their behaviour when in a mixture and also in order to quantify the accuracy of the signal processing method.

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Nsugbe, Ejay

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